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Cambridge, Massachusetts

LUMINARY Memo #76

To: Distribution
From: D. Eyles
Date: 1 April 1969
Subject: Variable Gains in Guidance Frame Erection

Before leaving (for a few days) I thought I would put out the results of the first short series of tests which exercise the variable gain capability introduced by PCN 756.

PCN 756 puts into erasable a "gain" factor to regulate the rotation of the guidance coordinate frame in response to azimuth redesignations. This appears as K in the equation that follows, which otherwise is the GSOP version of the second row of the guidance frame:

$$\underline{u}_{YGP} = \text{UNIT}(\underline{u}_{XGP} \times (4(\underline{r}_P - \underline{r}_{SP}) + K\,\underline{v}_{MP}\,t_{go}))$$

The smaller the gain factor the less the guidance frame rotates in response to azimuth redesignations. The implicit K of the old equation is unity; the old equation is matched now when the gain registers are loaded with POSMAX.

A gain less than unity improves the pointing of the window at the landing site. The window pointing routine, when the projection of the normal to the plane of the line-of-sight and the vehicle x-axis on the y-axis of the guidance frame becomes small, uses the guidance frame z-axis as its window vector. When the frame rotates after azimuth redesignations this projection becomes small at the same time as the z-axis of the guidance frame gets cocked off at an angle which is not the direction from the LM to the site.

The effect is an overshoot: when a sufficiently large number of azimuth redesignations occurs (more than four at least) the vehicle yaws too far toward the new site and points the window for a while to

the far side of it, making the reticle useless: the error after 6 plus azimuth redesignations is as much as 45 degrees.

When gain is less than unity the projection becomes less small and the line-of-sight is again used as the window vector.

A second effect of a less-than-unity gain is a less curved trajectory, in plan view, to the new site. The spacecraft turns further, sooner, and follows a tauter line to the site.

These tests were made as rollbacks of an old redesignation run on LUMINARY 88.

The redesignation schedule is as follows:

| | |
|---|---|
| 7 plus aximuth inputs | no wait |
| 4 plus elevation inputs | wait 7.5 |
| 2 plus azimuth inputs | wait 7 |
| 1 plus azimuth input | wait 9.5 |
| 1 plus azimuth input | wait 11.5 |
| 1 plus azimuth input | wait 60.5 |
| 1 minus azimuth input | wait 4.5 |
| 1 minus azimuth input | wait 16.5 |
| 1 minus azimuth input | wait 17.5 |
| 1 minus azimuth input | |

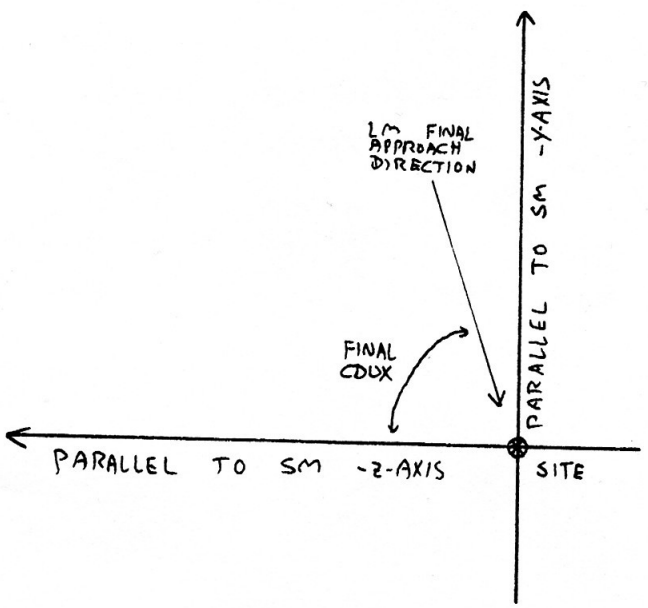
This begins about 20 seconds into the approach phase. These redesignations are (imperfectly) indicated by arrows on the plots that follow.

Superceded versions of the LM program and LM file were used and this is seen in the large RCS fuel expenditures.

The following is a list of the data provided and of some of the effects of lower gains that can be seen therein:

TABLE: Lower gains seem to get the LM above the site and into P65 more quickly, resulting in propellant savings.

Plots A, A', A'': (plots of CDUX & CDUXD during P64) These plots dramatically show the elimination of the window pointing overshoot. In this case for this purpose a gain of .875 is as good as .75. The less curved trajectory is seen in the final yaw angle, which is the final approach angle to the site.



Plots B, B', B'': (plots of CDUY & CDUYD during P64) These plots show the pitch profile.

Plots C, C', C'': (plots of CDUZ & CDUZD during P64) These plots show the tauter trajectory in the more extreme initial roll in the lower gain cases.

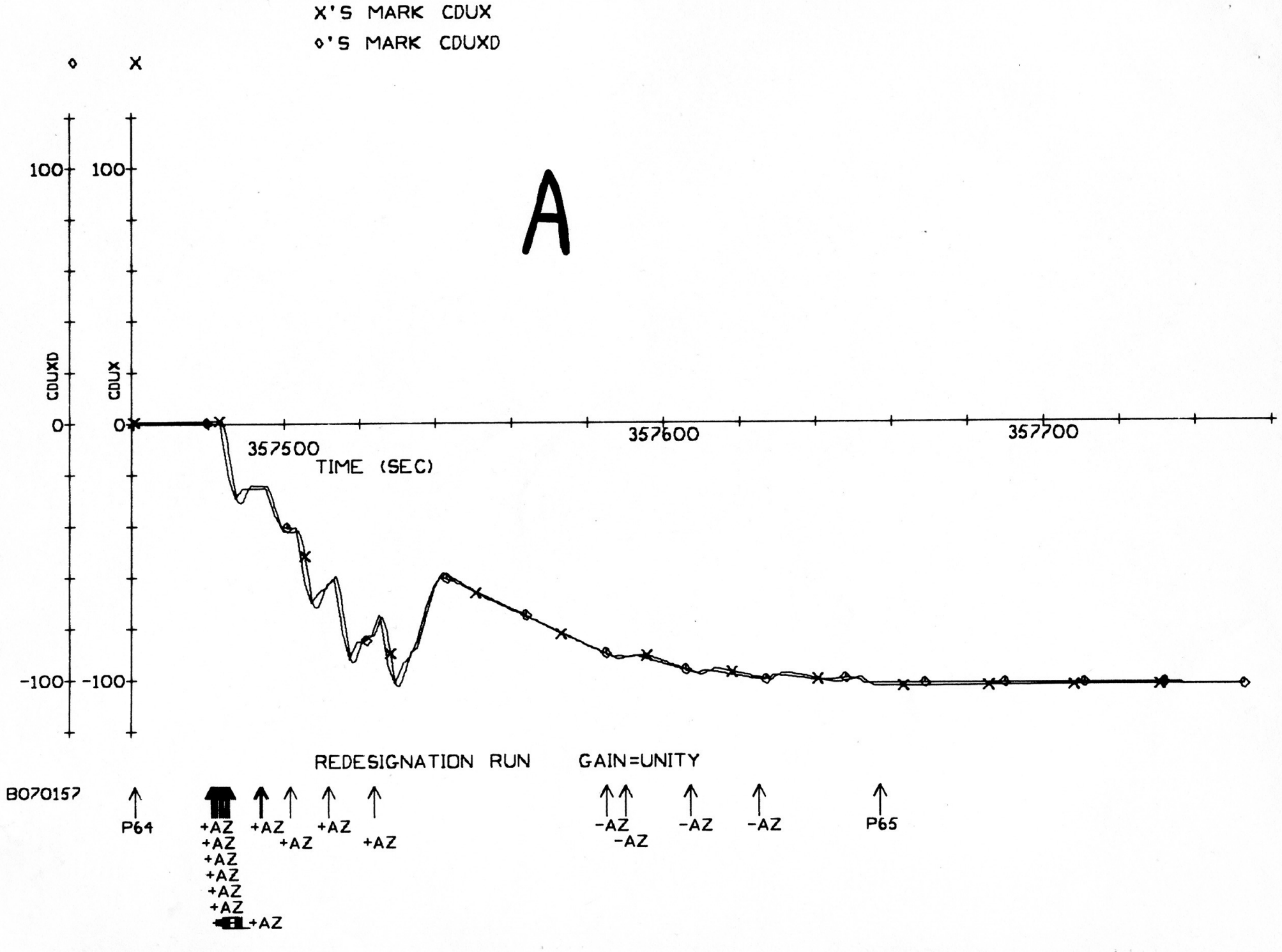
Plots D, D', D'': These plots of the spacecraft route (projected on the stable-member yz-plane) show the less curved trajectories that result from lower gains. If these had been plotted in a site-centered (rotating) frame the hook (-Z movement at the end) would disappear from the lower gain cases, and the actual approach directions of $75^{o}$ (for gain = .75) and $85^{o}$ (for .875) would be visible.

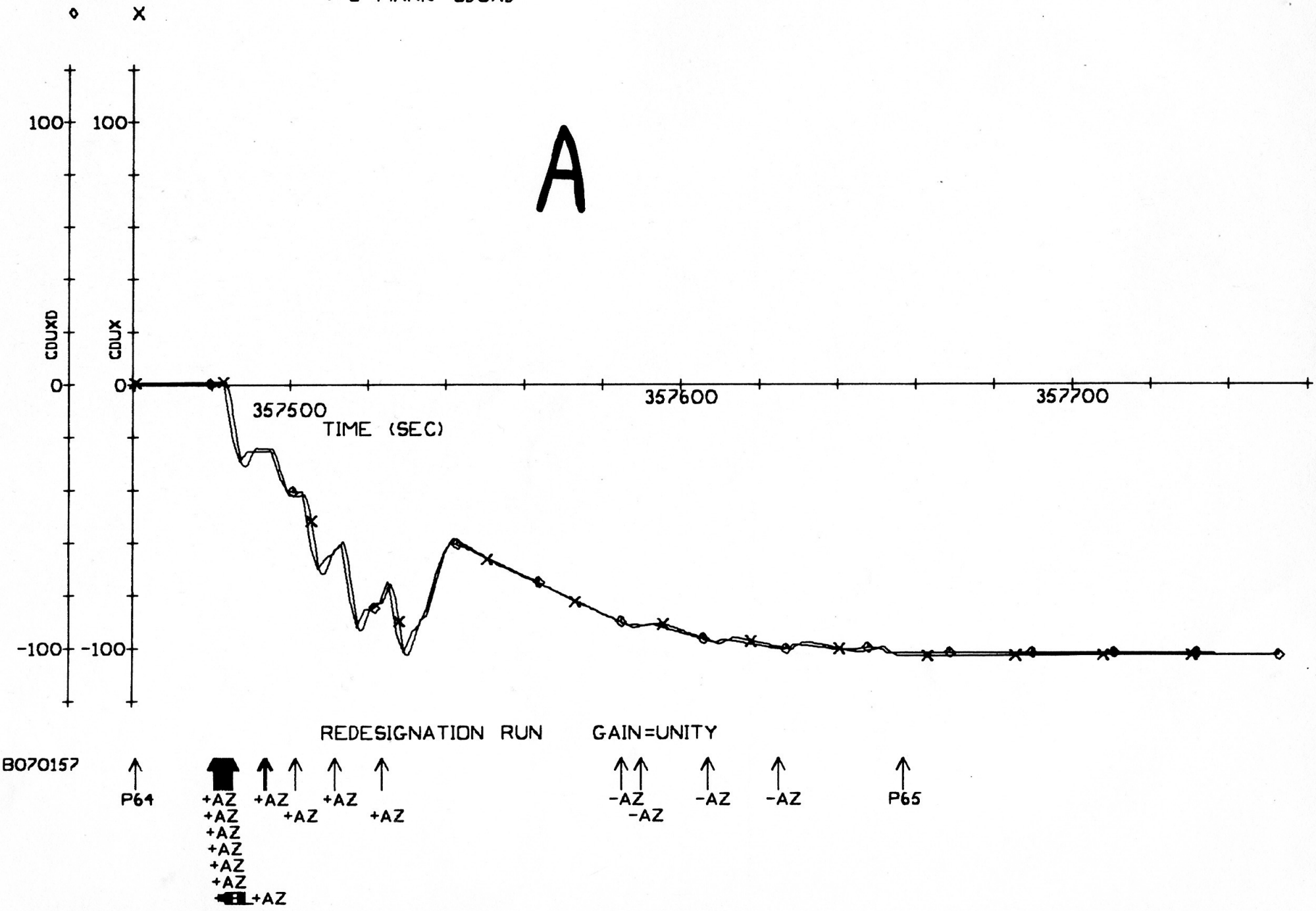
I was luckier with this series than with the earlier runs that produced the plots used at pre-faci - the printed output of which was lost in a system crash. Nevertheless these runs lack some useful output: it is not possible to see the elimination of the window pointing error in edits, only in the plots.

I shall make more runs. Allan is tooling up his MAC program and plans to study this gain flexibility there soon.

TABLE

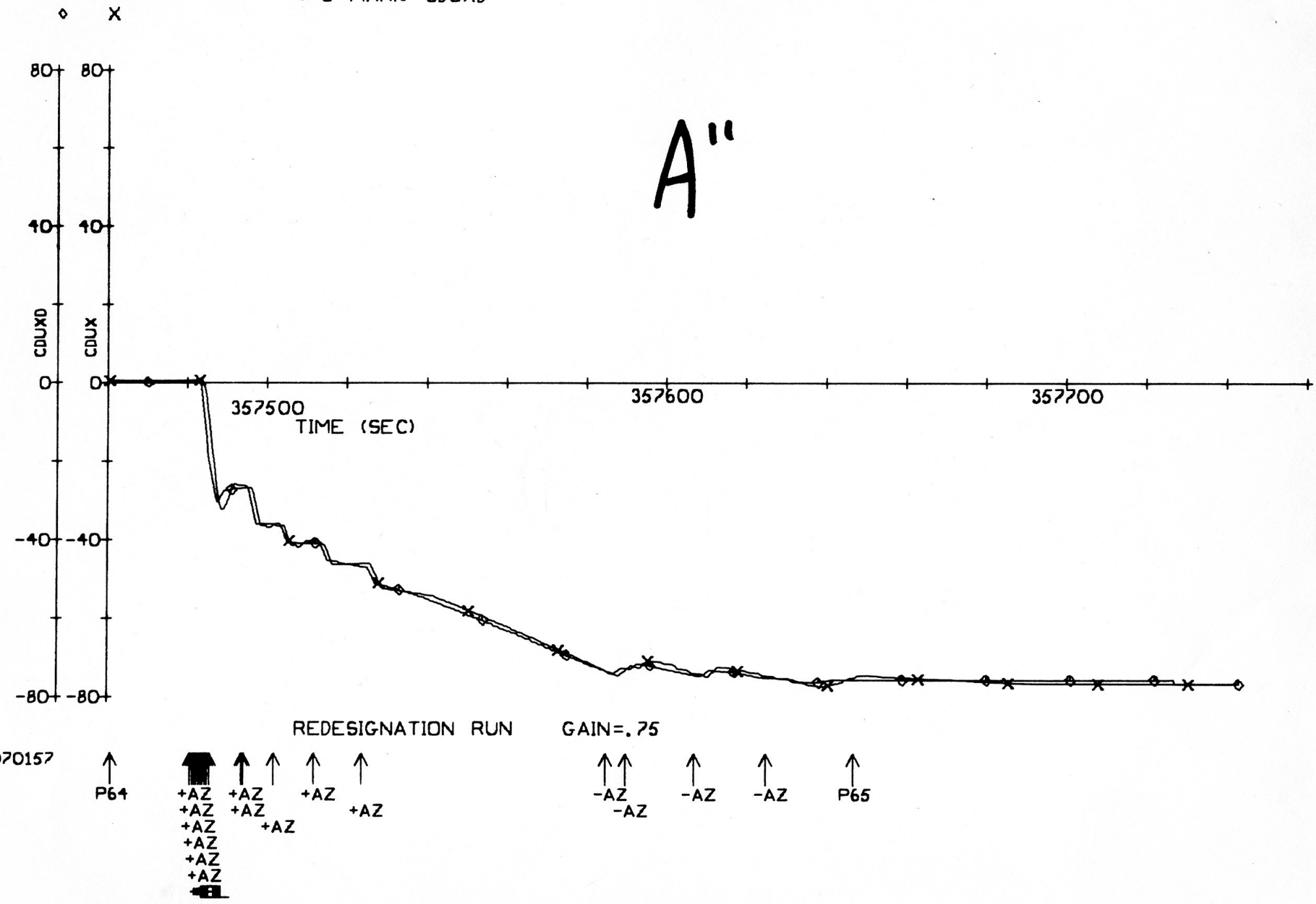
| | UNITY | .875 | .75 | |
|---|---|---|---|---|
| time of end of P64 | 357553.55 s. | 357649.55 s. | 357643.55 s. | (last approac phase pass) |
| final mass | 7181.18 kgs. | 7207.29 kgs. | 7228.06 kgs. | |
| RCS fuel used | 27.89 kgs. | 20.97 kgs. | 20.89 kgs. | |
| final CDUX in P64 | 103.15 deg. | 84.02 deg. | 75.27 deg. | |

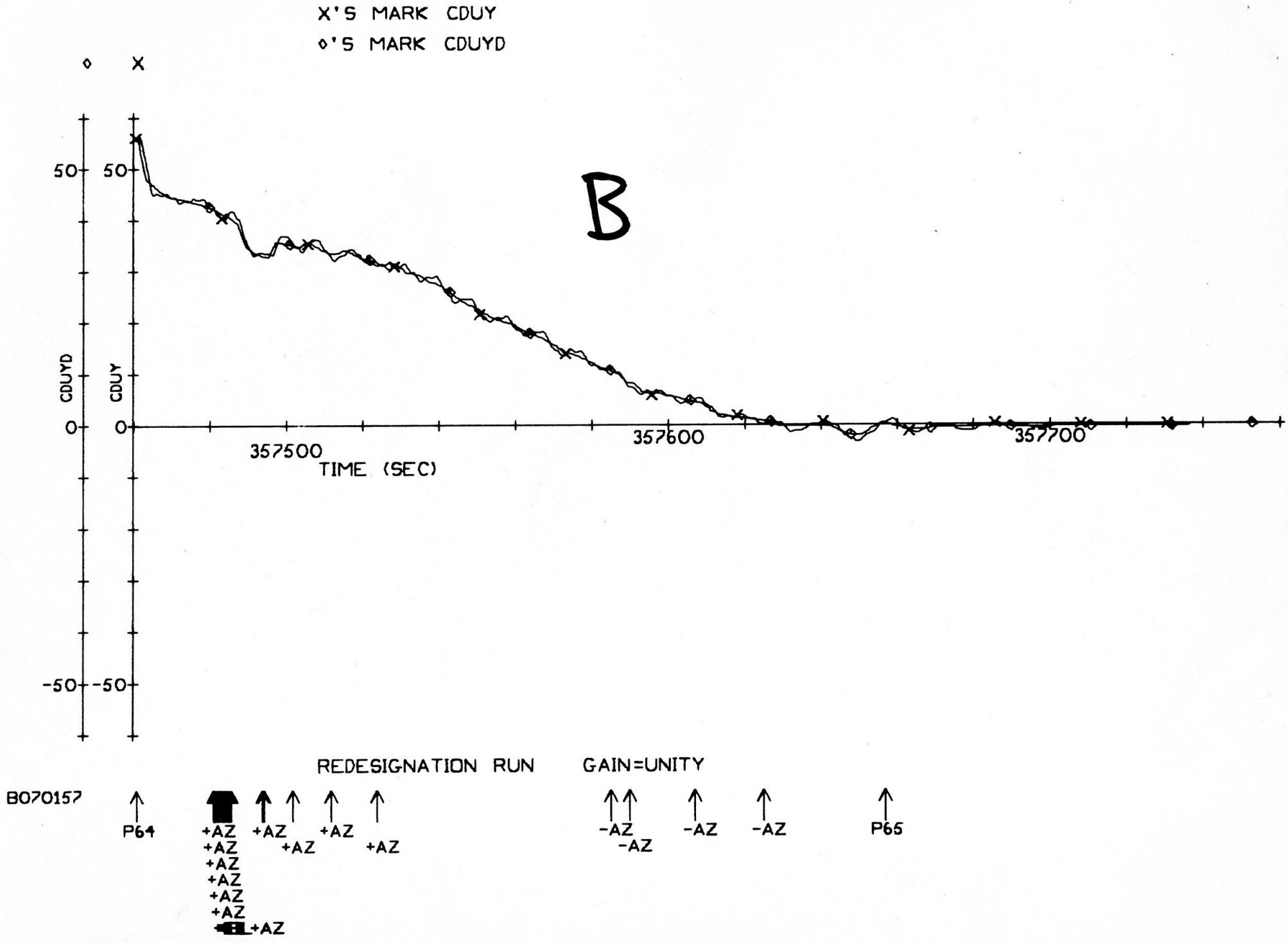

X'S MARK CDUX
◇'S MARK CDUXD
◇ X
100
100
A
CDUXD
CDUX
0
0
357500
TIME (SEC)
357600
357700
-100
-100
REDESIGNATION RUN
GAIN=UNITY
B070157
P64
+AZ
+AZ
+AZ
+AZ
+AZ
+AZ
+AZ
+AZ
+AZ
+AZ
-AZ
-AZ
-AZ
-AZ
P65


X'S MARK CDUX
◇'S MARK CDUXD
◇
X
A
100
100
CDUXD
CDUX
0
0
-100
-100
357500
357600
357700
TIME (SEC)
REDESIGNATION RUN
GAIN=UNITY
B070157
P64
+AZ
+AZ
+AZ
+AZ
+AZ
+AZ
+AZ
+AZ
+AZ
+AZ
+AZ
+AZ
-AZ
-AZ
-AZ
-AZ
-AZ
P65

X'S MARK CDUX

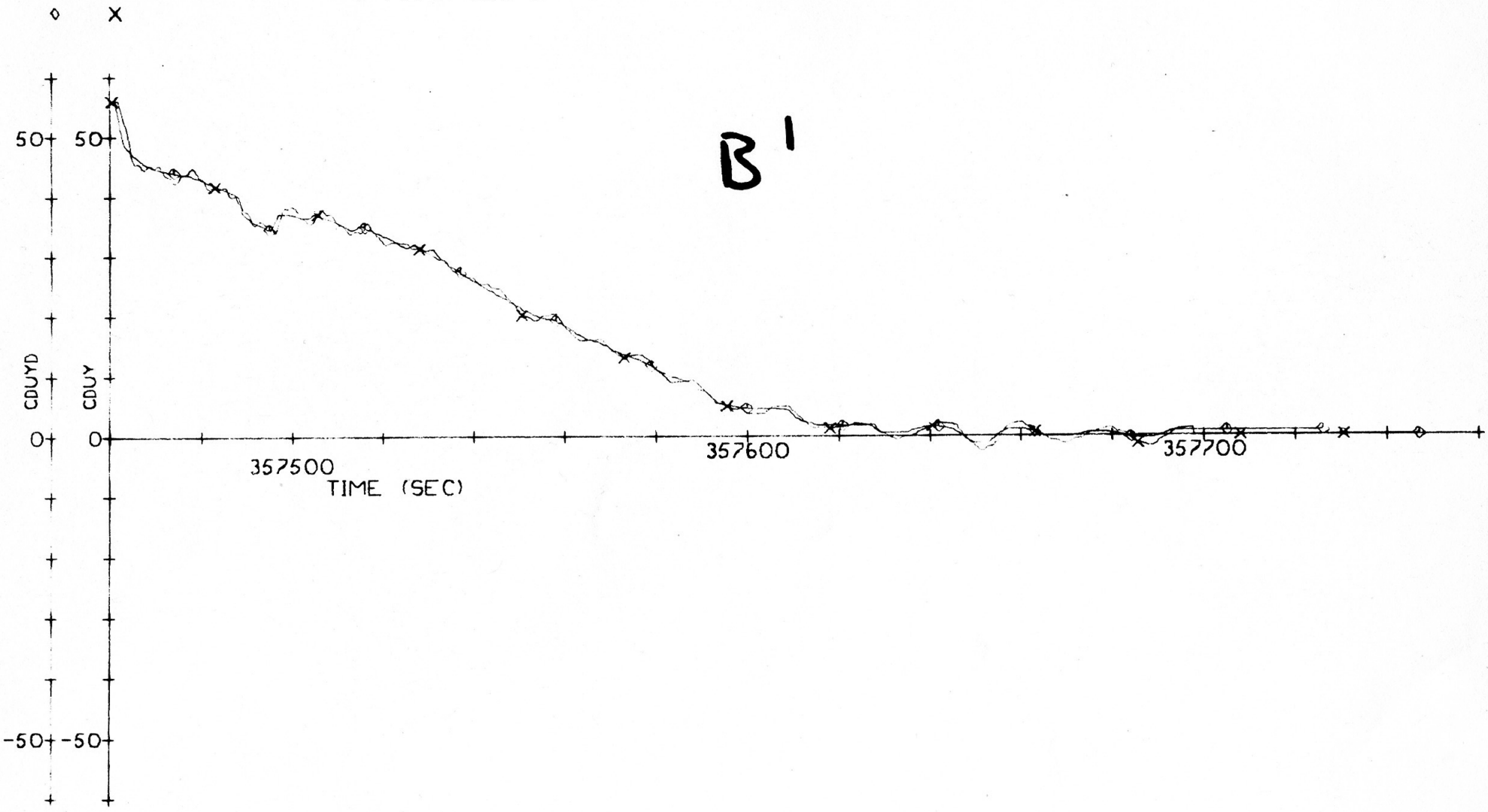
◇'S MARK CDUXD




X'S MARK CDUY
◊'S MARK CDUYD
◊ X
50
50
0
0
-50
-50
CDUYD
CDUY
B
357500
357600
357700
TIME (SEC)
REDESIGNATION RUN
GAIN=UNITY
B070157
P64
+AZ
+AZ
+AZ
+AZ
+AZ
+AZ
+AZ
+AZ
+AZ
+AZ
+AZ
-AZ
-AZ
-AZ
-AZ
-AZ
P65

X'S MARK CDUY

◊'S MARK CDUYD

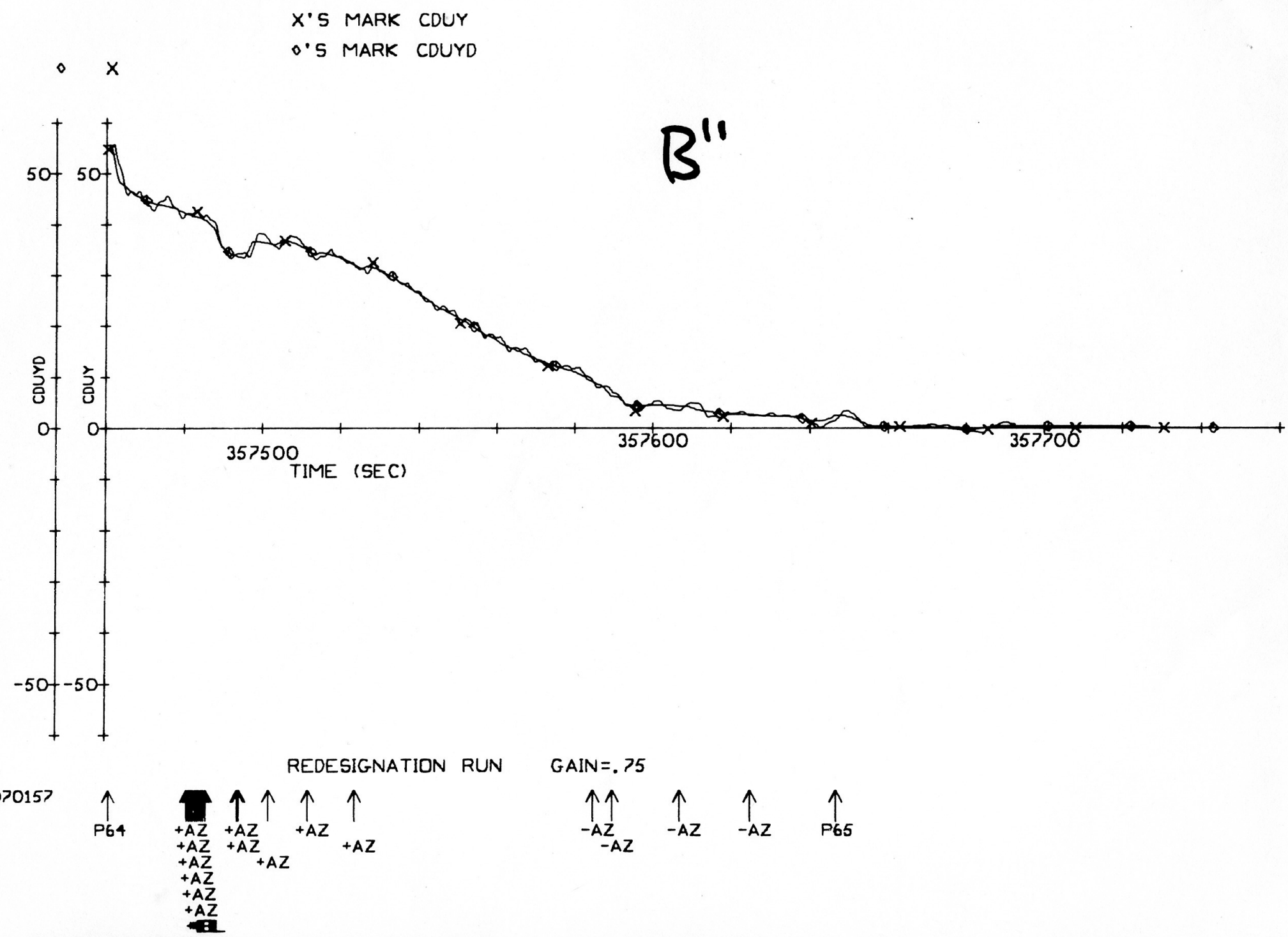


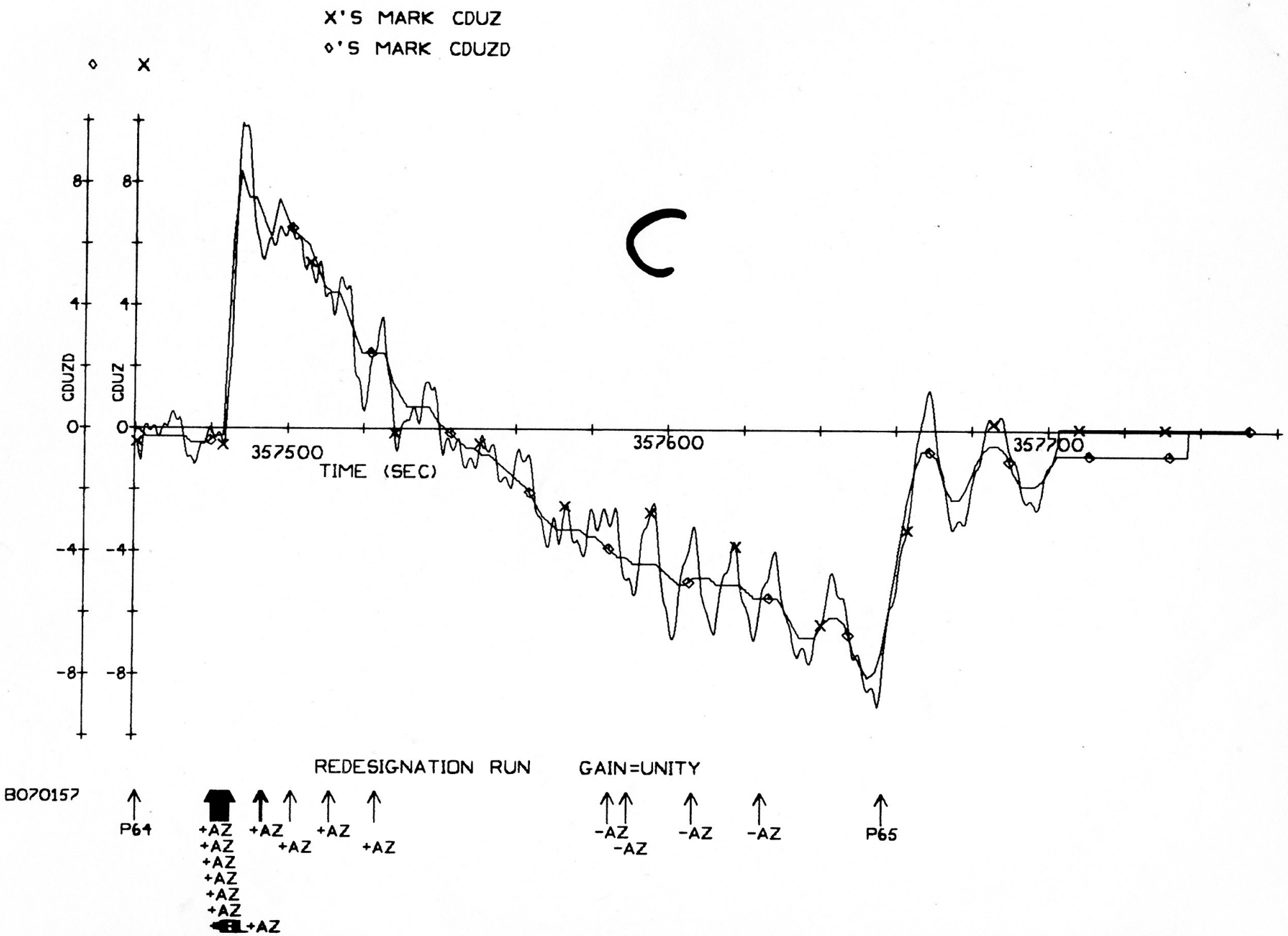

B 1

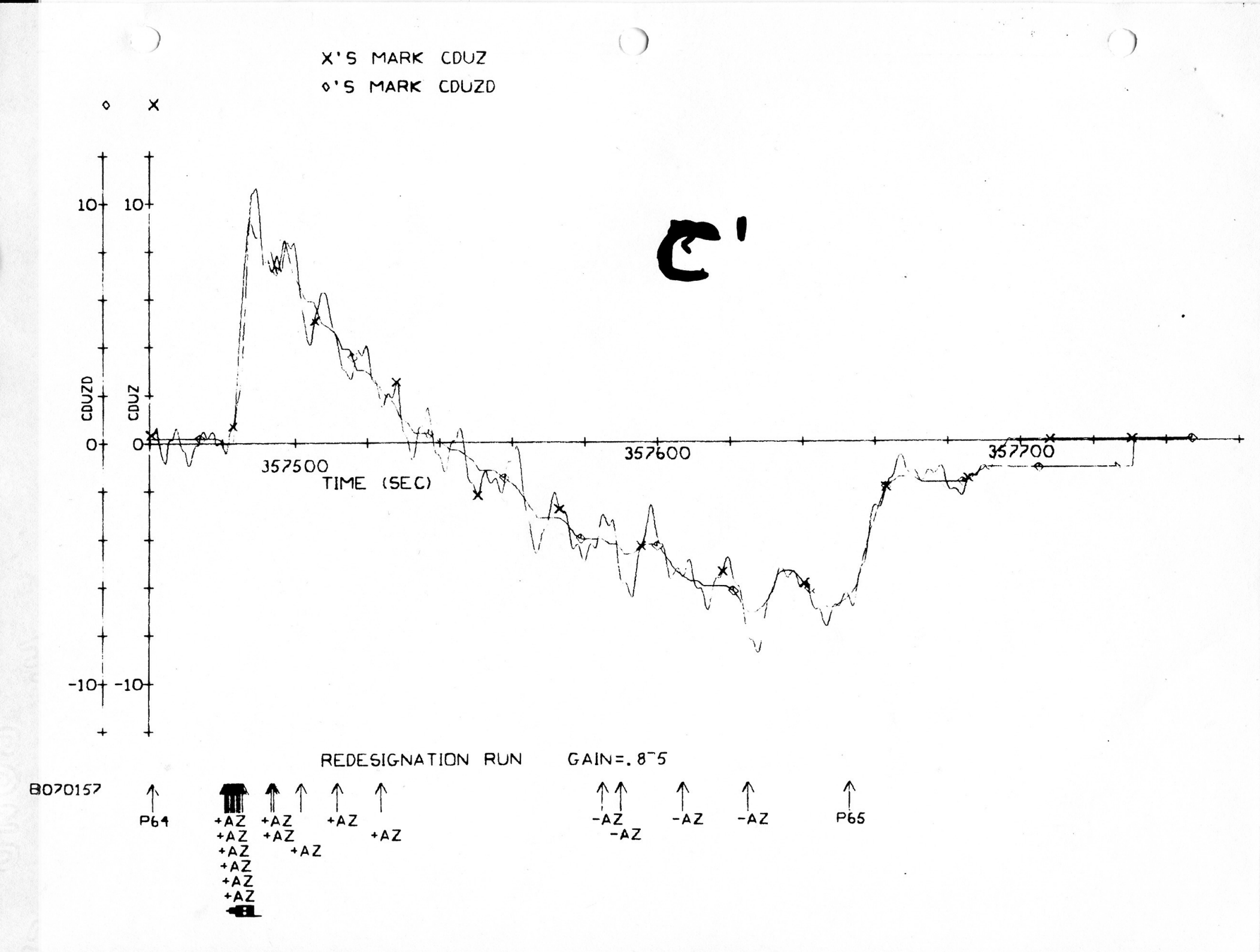
REDESIGNATION RUN GAIN=.875

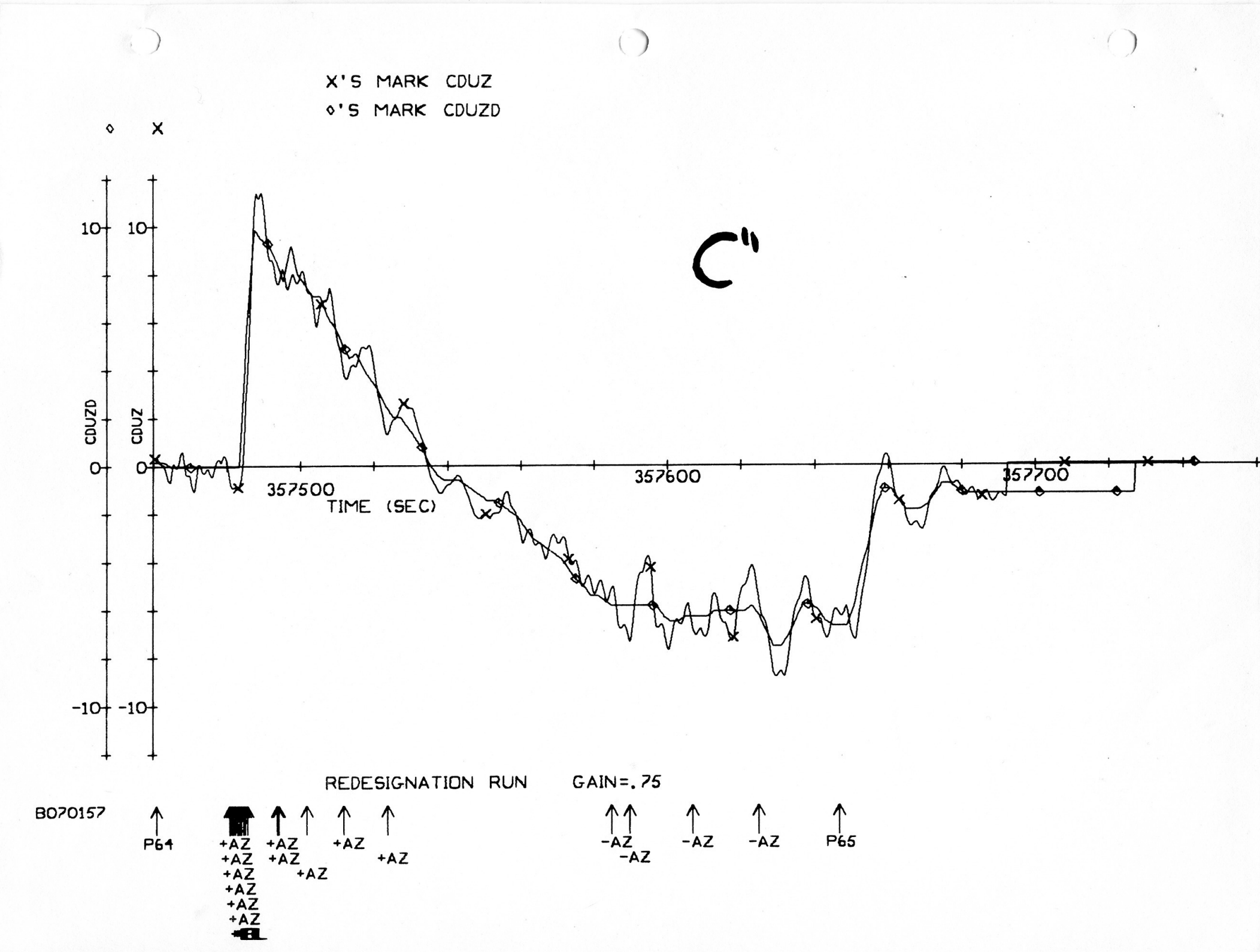
B070157

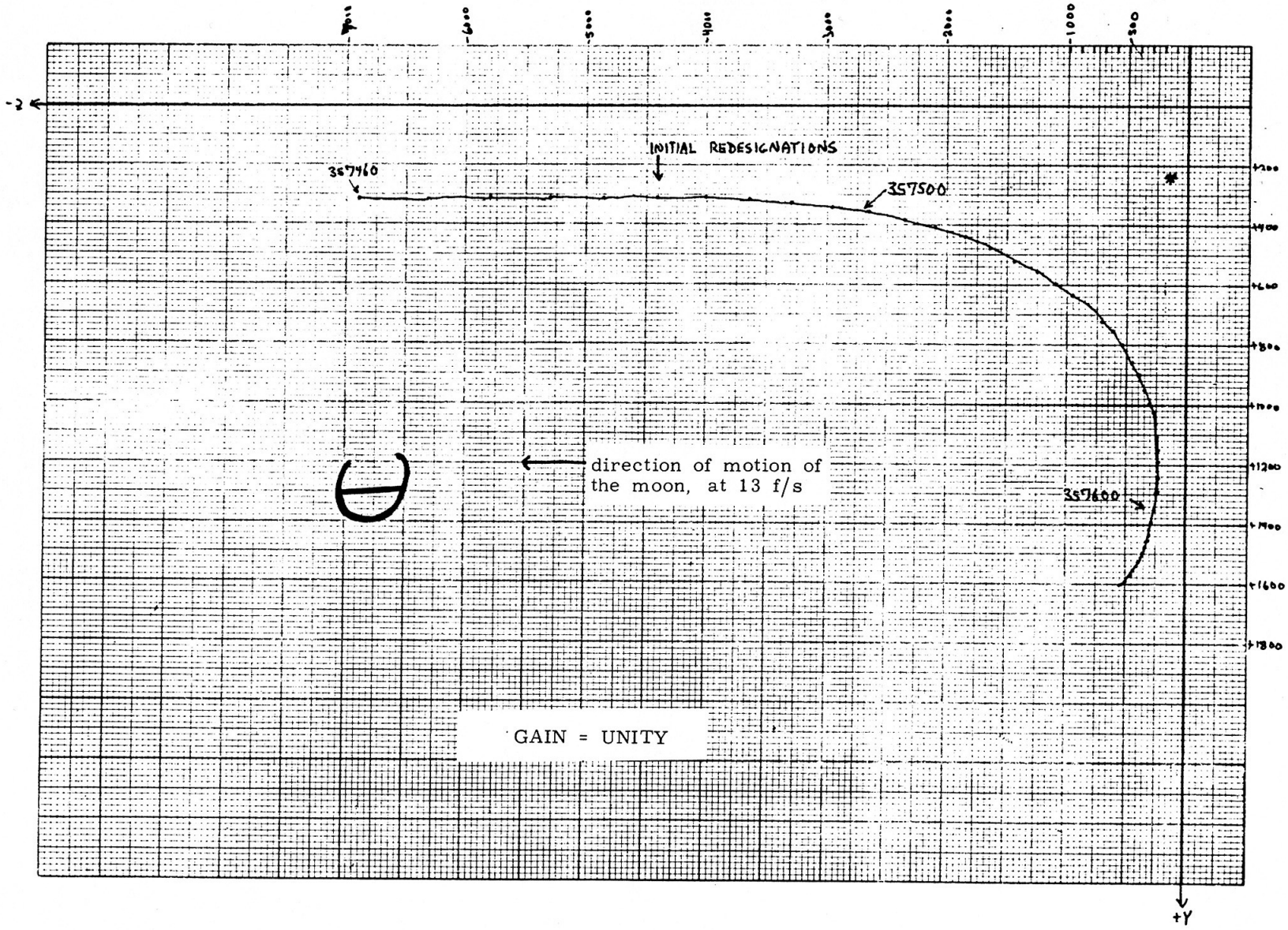
P64 +AZ +AZ +AZ +AZ +AZ +AZ +AZ +AZ +AZ +AZ +AZ +AZ -AZ -AZ -AZ -AZ P65

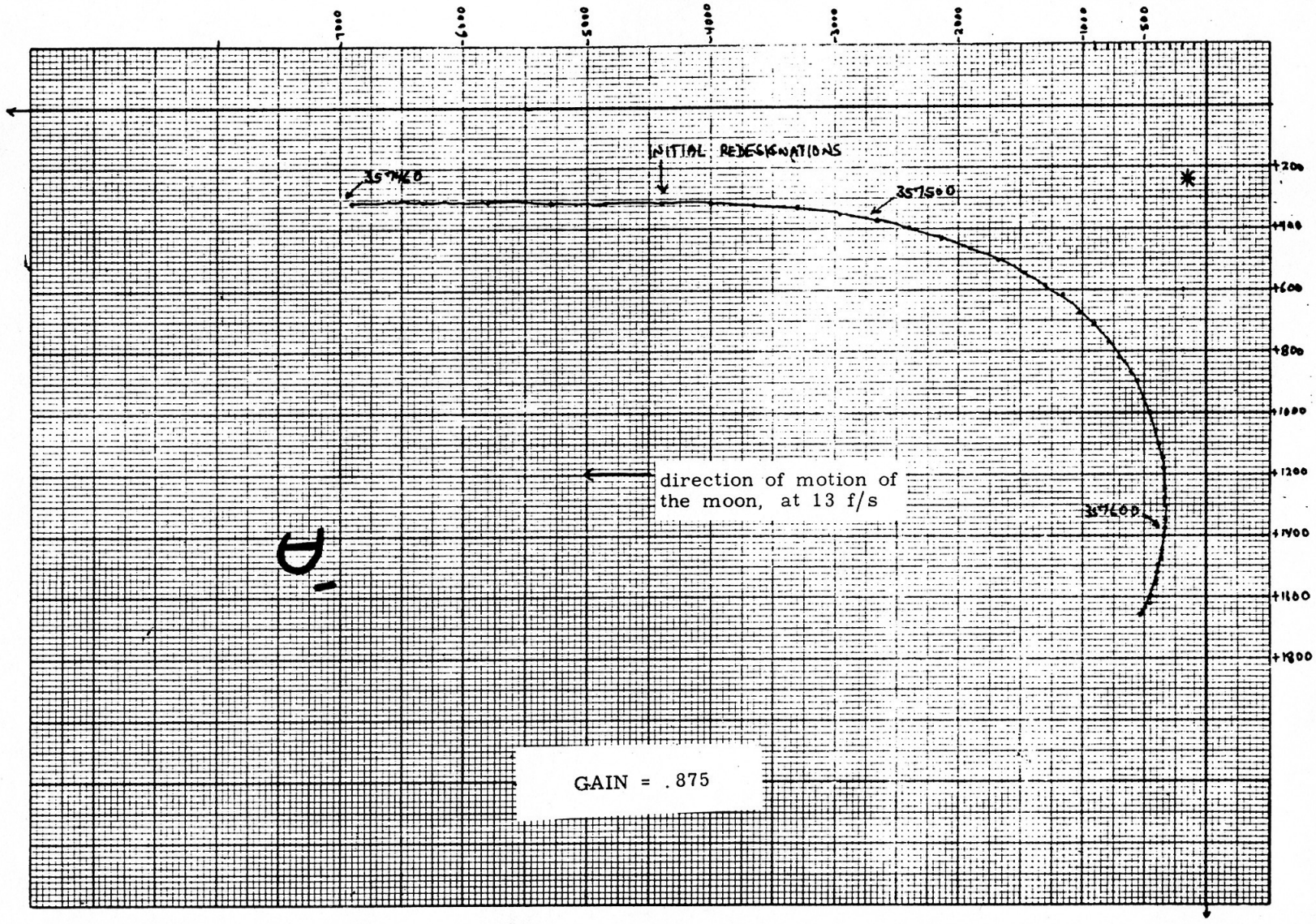

X'S MARK CDUY
◇'S MARK CDUYD
B11
50
0
-50
CDUYD
CDUY
357500
357600
357700
TIME (SEC)
REDESIGNATION RUN
GAIN=.75
B070157
P64
+AZ
+AZ
+AZ
+AZ
+AZ
+AZ
+AZ
+AZ
+AZ
+AZ
-AZ
-AZ
-AZ
-AZ
-AZ
P65

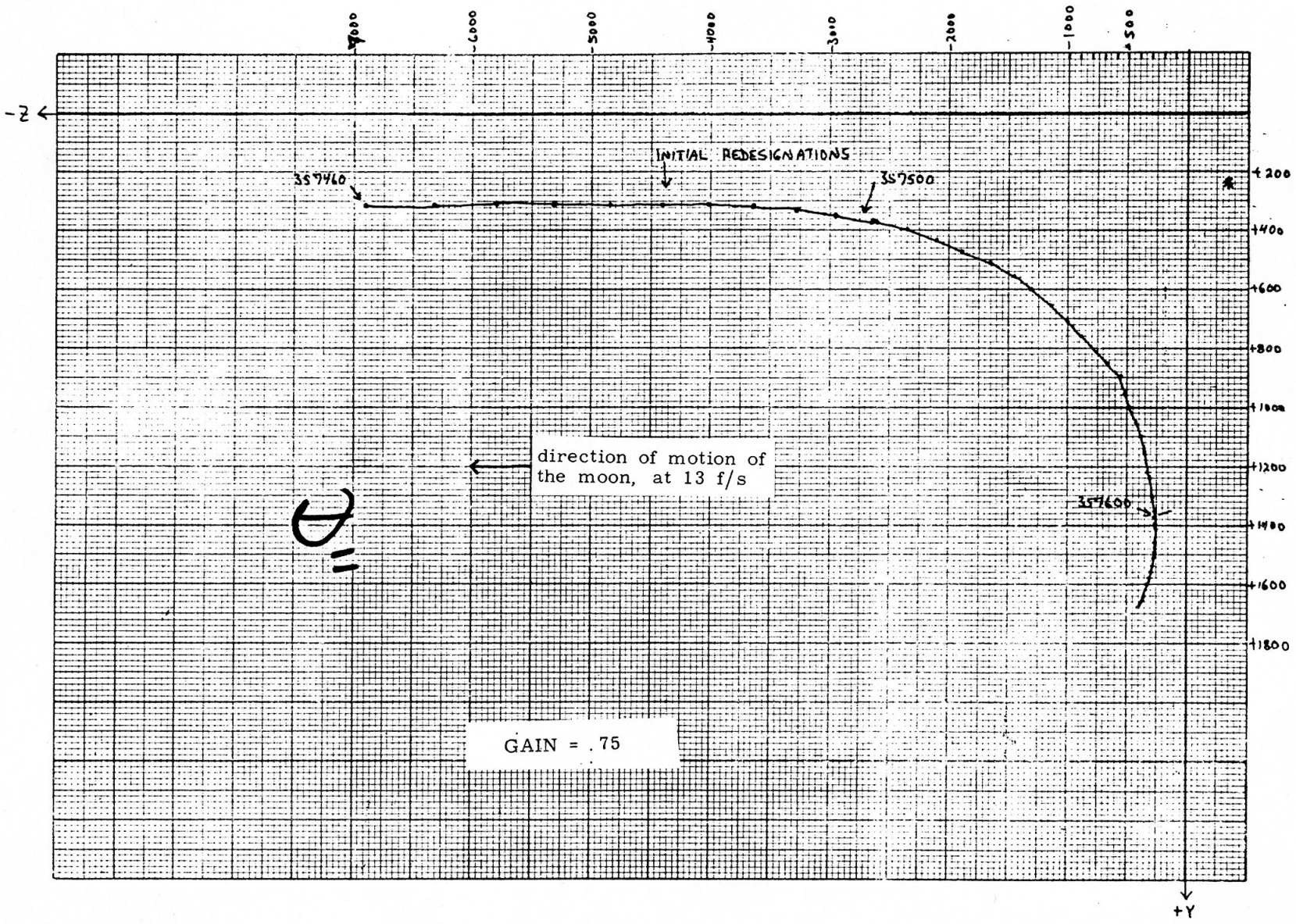

X'S MARK CDUZ
◇'S MARK CDUZD
◇ X
8
4
0
-4
-8
CDUZD
CDUZ
357500
357600
357700
TIME (SEC)
REDESIGNATION RUN
GAIN=UNITY
B070157
P64
+AZ
+AZ
+AZ
+AZ
+AZ
+AZ
+AZ
+AZ
+AZ
+AZ
-AZ
-AZ
-AZ
-AZ
-AZ
P65


X'S MARK CDUZ
◊'S MARK CDUZD
◊ X
10
10
0
0
-10
-10
CDUZD
CDUZ
357500
TIME (SEC)
357600
357700
REDESIGNATION RUN
GAIN=.8^-5
B070157
P64
+AZ
+AZ
+AZ
+AZ
+AZ
+AZ
+AZ
+AZ
+AZ
+AZ
+AZ
-AZ
-AZ
-AZ
-AZ
-AZ
P65


X'S MARK CDUZ
◇'S MARK CDUZD
◇ X
10
0
-10
CDUZD
CDUZ
357500
357600
357700
TIME (SEC)
C"
REDESIGNATION RUN GAIN=.75
B070157
P64
+AZ
+AZ
+AZ
+AZ
+AZ
+AZ
+AZ
+AZ
+AZ
+AZ
+AZ
-AZ
-AZ
-AZ
-AZ
-AZ
P65


-2
INITIAL REDESIGNATIONS
357460
357500
357600
direction of motion of the moon, at 13 f/s
GAIN = UNITY
+Y


INITIAL REDESIGNATIONS
35760
35750
35700
direction of motion of the moon, at 13 f/s
GAIN = .875


-7000
-6000
-5000
-4000
-3000
-2000
-1000
-500
-Z
INITIAL REDESIGNATIONS
357460
357500
357600
+200
+400
+600
+800
+1000
+1200
+1400
+1600
+1800
direction of motion of the moon, at 13 f/s
GAIN = .75
+Y